DESIGN OF HEALTH SYSTEMS

BY

B. S. SHANKARA

DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

SEPTEMBER, 1972

DESIGN OF HEALTH SYSTEMS

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of

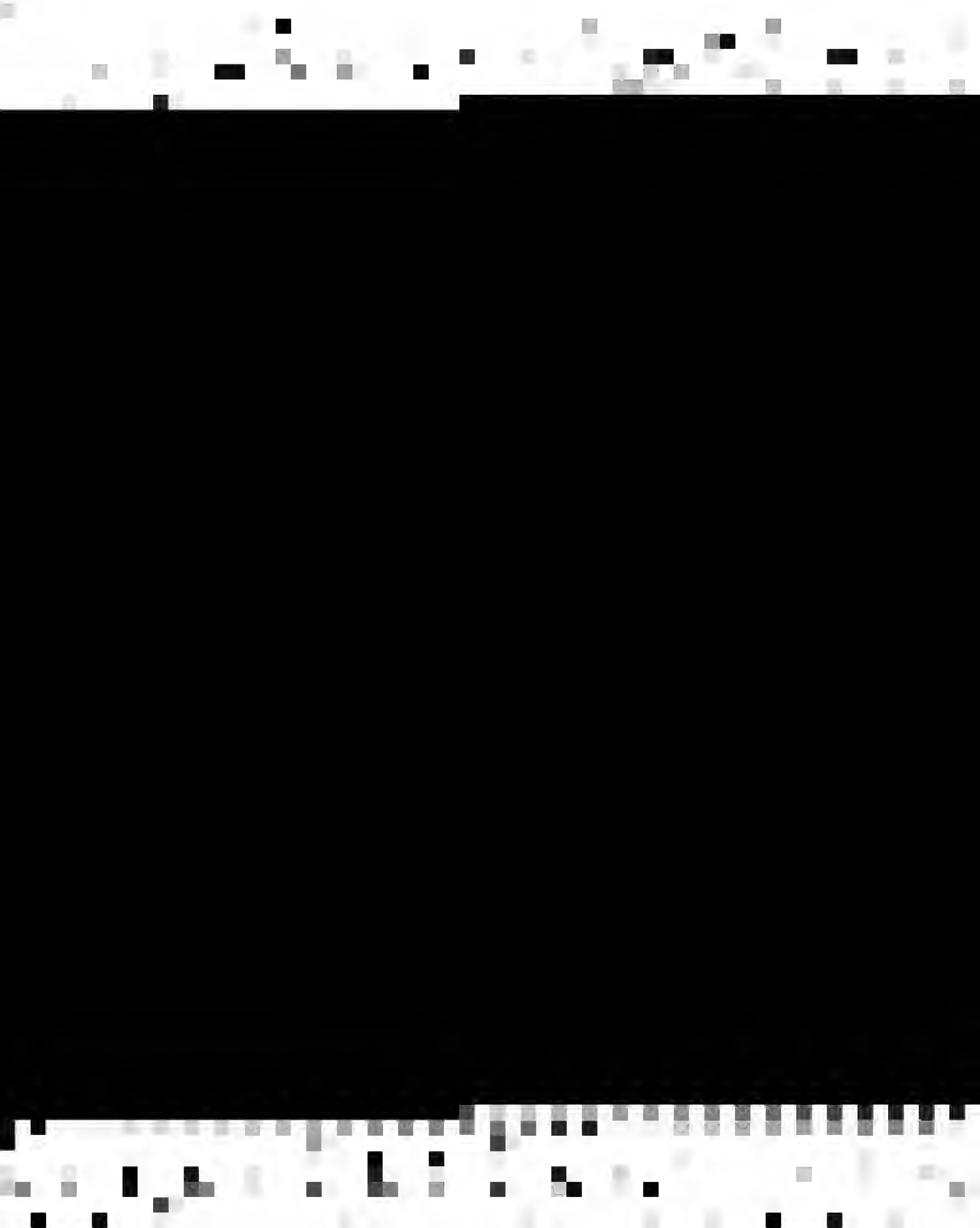
MASTER OF TECHNOLOGY

by

B.S.SHANKARA

to the

Department of Mechanical Engineering
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR
SEPTEMBER 1972



CERTIFICATE

This is to certify that the thesis entitled "Design of Health Systems" by B.S. Shankara is a record of work carried out under my supervision and has not been submitted elsewhere for a degree.

B.L. Dhoopar
Associate Professor
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

September 2, 1972

ACKNOWLEDGEMENT

To Dr. B.L. Dhoopar but for whose constant guidance encouragement, and useful suggestions to approach the problem, this thesis would not have taken its shape, and who time and again devoted his useful hours for this work, I would pray

गुरुब्रह्म गुरुविष्णु:
गुरुदेवो महेश्वर:
गुरु साक्षात् पर ब्रह्म
तस्मै श्री गुरुवे नम:

I am highly grateful to Dr. L.S. Srinath who introduced to me the area of systems engineering and suggested the problem of health care delivery systems. With his beaming knowledge of several systems he enlightened me in applying the most common ideas of individuals to solve system problems. Thanks are due to Dr. V. Sundararajan, Dr. H.C. Parameshwar who part took in brain storming sessions, and offered creative ideas. To Dr. J.D. Borwankar of Mathematics Department, I am highly grateful for his valuable criticisms.

I am thankful to Dr. Iqbal Krishan, Medical Officer, Georgia Institute of Technology, for his expert advice on medical systems and helpful criticisms on the solutions arrived at. Thanks are due to Dr. M.B. Borwankar, Medical Officer,

Dr. K.P. Gupta, Dr. Mrs. Kulakarni, Dr. Mrs. Sheela Srivastava, Dr. Chandra, and Dr. Manglik, for their timely help in collecting data from the health centre. I am also indebted to health centre staff for several helpful actions.

My thanks are due to Mr. Satyender Singh, Asstt. Engineer, Institute Works Department, Mr. Bhatnagar of Water Works, and Mr. Saxena of Sanitary Division. Many persons have given their ideas and information during the environmental study. To all of them I remain thankful.

The earlier portion of the work is a combined effort. My collegues Mr. Subrhmanya Shastry and Mr. M.S. Nagaraj Murthy, very well co-operated with me. They were helpful in hammering out several ideas regarding the system. I am grateful to them.

Within the short period of urgency Mr. D.P. Saini has done a splendid job of his profession. My sincere thanks are due to him.

Last but not the least, I am thankful to Mr. T.K. Suresh who helped in carrying out data collection work.

B.S. SHANKARA

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SYNOPSIS

of the
Dissertation on

DESIGN OF HEALTH SYSTEMS

Submitted in Partial Fulfilment of
the Requirements for the Degree

of

MASTER OF TECHNOLOGY

in

MECHANICAL ENGINEERING

by
B.S.SHANKARA
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

In the present work systems approach has been adopted for the design of health delivery systems for I.I.T. - Kanpur community, or communities similar to this. For synthesis of alternative solutions study of existing health centre and its environment has been undertaken. Feasibility of various alternatives have been analysed. The best alternative is a combination of a consultation centre, health workers programme and an elaborated health education programme. The system arrived at is similar to one which exists in its present form.

The best alternative is not justified due to difficulties encountered in mathematically formulating the system. A step has been taken in this direction in modelling the system for its demand estimation of services. The results of the modelling are higher than the actual consumption. This discrepancy is explained on the basis of number of difficulties faced in quantitatively formulating the system.

CHAPTER 1

INTRODUCTION

Health is the primary concern of all of us. It is essential that proper health of the citizens of a country be maintained so as to upkeep the progress of the country. A broad national policy is needed to tackle the problem of health care in a country. In addition, regional needs of health care are also to be met. For this, comprehensive regional planning is essential. Even though health delivery systems may exist, efficient management is required for their proper functioning. In a country like ours, delivering health to every village needs a sound policy, a connected network of regional health delivery units and a well co-ordinated organization.

To solve this national problem, a systems approach need to be adopted. This approach tackles the social need in a comprehensive manner leading to the detailed design of its elements. It is a methodology carrying out synthesis of solutions and evaluation of the system in a chronological order. For each step in the chronological order, detailed solutions are obtained by feeding information .

1.2 Importance of Industrial Engineering in Health Industry:

The national health problem is enoromous and involves a complex set of local health problems. National health problem is to be solved on a macro level whereas the regional health problems are to be solved on micro level. Systems approach is a novel methodology which can be applied to both the problems, irrespective of their magnitude.

It is a fact, from the view of diagnosis and treatment, that the proper functioning of health delivery units is very much dependent on the physicians. Progress in medicines and research in medical field are the two factors that help in keeping away chronic diseases in a country. Nevertheless efficient utilization of available facilities is very important, so that maximum possible care is given to patients. Also because of lack of facilities, physicians shall not be restricted in utilizing their specialied knowledge in curing the illness. Often it is a matter of unavailability of proper facilities that has led to disastrous ends. Hence it is important that the design of every regional and local health delivery unit be carried out from maximum utility point of view. It is in this aspect of the design that the application of the techniques of industrial engineering is also called for.

1.3 Application of Industrial Engineering to Health Industry:

The definition of Industrial engineering as adopted by Institution of Industrial Engineers (1) is

[redacted]

"Industrial engineering is concerned with the design, improvement and installation of integrated systems of men, materials and equipments. It draws upon specialised knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems". It is clear from this definition that its applications are called for in the design and improvement of a system involving interactions of men materials and equipments. Thus the health delivery system is similar to an industry. Viewed as an overall system, health industry has to have a well defined organisation and needs good management for its efficient working. Health industry has a similarity to production industry in problems of men, materials and equipments. Whereas in the later it is the coordinated action of machines and materials together with the skill of operators that is important, in the former it is the maximum utility of physicians' professional competence and the available facilities. Though most of thoughtful actions are called for from the physicians knowledge, his usefulness is increased tremendously if it is supported efficiently by the supporting staff and equipment. Thus one finds a lot of scope for the applications of Industrial engineering to health delivery systems.

1.4 Areas of Health Industry Where I.E. can be Applied:

Having seen the suitability of Industrial engineering

to health industry, areas of this industry where the techniques of I.E. can be applied are to be explored. Some of the major areas where I.E. can be applied are (2).

1. Setting up of the organisational responsibilities.
2. Management and co-ordination of staff.
3. Selection, training and education of staff.
4. Economic and financial evaluations for running the system.
5. Control of material flow in various department.
6. Work study and methods improvement of the hospital activities.
7. Inventory keeping of various consumable materials.
8. Demand estimation of materials.
9. Organisation of data processing systems for speedy feedback.
10. Waiting line problems and improvement of waiting times.

As mentioned earlier, for finding solutions to system problems through systems approach, exhaustive information is needed during solution steps. Where stored information is not available, studies have to be made and information gathered. One such study is a micro level analysis of demand estimation. It is from this view of point, that a problem in demand estimation is also attempted in the present work.

The second chapter in the thesis deals with the systems approach of finding alternate solutions to health needs of IIT.K community. Systems approach is used as a

methodology to study, analyse and sythesize various feasible solutions to health care problems. First a needs statement of the health problem is made. As the campus has already an existing health centre, a study has been conducted for the collection of information on the system and its environment that is the campus health centre and campus environment.

The third chapter deals with the problem of estimation of demand for various services in the existing health centre. Modification of an earlier model (12) to suit the situations of Indian hospitals is given. The model includes a preventive curing aspect also. Sample data collected on the campus health centre and the results obtained from the model are given in the fourth chapter.

CHAPTER 2

SYSTEMS APPROACH TO I.I.T.-K.HEALTH DELIVERY PROBLEMS

It is mentioned in the introduction that regional health delivery centres can be best designed through systems approach. If a regional health centre is already working, its performance can be improved through its system analysis. In the present work, design of a health delivery system for I.I.T-K. community has been considered. The existing health centre has been analysed for possible improvements.

2.2 Asimow (3) in his book on "Introduction to Design" states that the first step in the systems approach is the needs analysis, which, in the case of health delivery at I.I.T-K is stated as follows. "I.I.T.-K campus is located away from Kanpur city. The community on the campus consists of students, faculty members and support staff, engaged in a specific activity. Like any other community elsewhere, the members of the campus community are also prone to all kinds of diseases and seek medical help in case of illness. Due to the campus location, they are unable to utilise medical facilities available in the city. To upkeep activity in which the community is involved, individuals should maintain good health. The Institute administration should provide proper arrangements

for the medical facilities. Hence a need to solve the present problem". This is the broadest possible need statement.

2.3 Environmental Study:

2.3.1 The second step in the systems approach is the study of environment (3) "In a natural system of plant and animal life, the system develops itself by its interaction with the environment" (3). In a similar manner, man made socio-ecological system, like a health delivery system, has an interaction with its environment during its active life. Let the health delivery system be represented by a black box. The input to this box are several variables and parameters from its environment. Variations in these input quantities affect the performance of the system, and its outputs. (Figure No. 1) Hence for a proper understanding of the behaviour of the system, a study of the system and its environment is essential.

In the present work, the environment of the I.I.T.-Kanpur health centre is the campus community and its surroundings. A study of this environment is conducted.

2.3.2 The study of the whole health system is divided into two parts:

1. Study of the health centre* (as the main system)

and 2. Study of the environment.

* Conducted by co-worker of the author (10)

The first part, conducted by the author, is described below in the following sections:

(i) Location of the campus and its surroundings.

(ii) Type of the community and its activities.

and (iii) Facilities provided on the campus.

(i) Location of the Campus and its Surroundings:

The campus of I.I.T.-Kanpur is located in northern part of India. It is about 12 kilometers from the centre of the city. The climatic conditions are extreme in the major portion of year. Because of its location, at present, the campus is not conjested by adjacent growth of other communities.

An air pollution study (4) of the city atmosphere has been conducted. I.I.T.-Kanpur campus was selected as one of the sample collection stations. The study shows that the campus air is polluted but not to a hazzardous level. However, a number of brick kilns and a thermal power plant are situated around the campus; and there is a possibility of additional industrial growth. This may threaten the purity of air in future. Also in the surroundings of the campus, there are some villages where the awareness of sanitation and good health is relatively low. A number of persons from these villages enter the campus daily, as milkmen, washermen, vendors of ice cream and vegetables etc. In case an epidemic errupts in these villages - the probability of that being very high - the villagers will carry and communicate the epidemic in the campus community.

(ii) Type of the community and its Activities:

The community on the campus can be broadly classified in the order of its population as below:

a. Support staff and their families.

b. Students,

and c. Faculty members and their families.

Awareness of sanitation in the first group varies from very poor to normal, where as it may be near normal amongst the other two groups. The above mentioned groups, constitute the centre engaged in learning and research which are the main activities of the campus.

(iii) Facilities on the Campus:

To sustain normal life on the campus, various facilities are provided. Those which are important from health point of view are:

a. Water supply.

b. Sanitation.

c. Health care facilities.

d. Hostels and residences.

Information collected on these facilities is listed below.

a. Water Supply:

Campus water supply is by tube wells. Water is supplied directly from the tube wells, without storage, after treating it with bleaching powder. Enquiries made from officials in Institute Works Department reveal the following

[redacted]

1. Supply water is eligible for both drinking and domestic purposes.

2. Contaminants of water are within the level prescribed by World Health Organization (5). Analysis of campus water and the W.H.O. specifications are given in Table 5.

3. An average daily percapita supply of 128 gallons of water is maintained in the non-scarcity seasons (6). This is far above the minimum prescribed by W.H.O. which is 60 gallons percapita per day.

4. Scarcity of water occurs only for two months in which period, the daily supply falls from a regular supply of 9 lakh gallons to 7 lakh gallons.

In the light of the information given above, the discussions with the medical expert (Dr. I. Krishan) revealed that there is less possibility of contracting diseases on the campus, either due to scarcity of water or through impurities in water.

b. Sanitation on the Campus:

The extent to which sanitation facilities are well maintained on the campus has a direct effect in reducing the load on the health delivery system. It also is a factor in keeping away epidemics and endemics from the campus community. Information on the sanitation of the campus is collected from Institute Works Department, by direct observations, and from earlier studies (6,7,8 and 9). These informations are listed below:-

i) Sewerage:

1) Human refuse and waste water of the campus is collected through a network of underground sewerage lines. The sewerage collected is carried to an oxidation pond which is about 1.5 kms. away from the residential area.

2) Sewerage is untreated and only exposed to natural action like sun rays.

ii) Garbage:

1) Campus garbage is collected from residential quarters, hostels and other public places by a system of cans installed at several places in the campus. However, less attention is paid to the most populated area of the campus, viz, Type 1 quarters. Garbage collection from the cans of this region is irregular and the cans are without lids. As a result of this overfilling and spreading occurs. This creates feeding places for flies, birds and animals.

2) There is an inadequacy of garbage collecting wheel-barrows. The only van for collecting and transporting the garbage has insufficient capacity resulting in the increased number of trips from a place of garbage storage to dumping site.

3) Transported garbage is dumped in natural pits at the entrance of the campus. Standard method of composting, which requires covering the dumped garbage

with a layer of soil, is not followed.

iii) D.D.T. and Insecticide Program:

The Institute Works Department has a D.D.T. program to control the mosquito population. Information collected is as follows:-

1) Regular schedule of D.D.T. spraying is not maintained.

2) Refusal for a D.D.T. spray is encountered in some places due to lack of awareness.

3) D.D.T. supplied by outside agencies is not subject to any quality inspection prior to its use.

c. Health Care Facilities:

For the reasons mentioned in the needs analysis, a health centre is provided in the campus to treat common diseases of the residents. Its detailed study is conducted by the co-worker (refer M. Tech thesis of Mr. Nagaraj Murthy (10)). The health centre has outdoor, indoor and X-ray units. For emergency cases and for diseases requiring specialised treatment, liaison with the city hospitals is established. Ambulance facility is provided for all emergency services. From the study of the existing health centre (10), details of Organizational structure, Various facilities provided and duties of personnel are given in Tables 1, 2, 3 and 4.

d. Hostels and Residences:

The student community is housed in six residential hostels. Each hostel has a mess and the food supplied in all

messes is of the same standard from the health point of view. The cleanliness of cooks and bearers was observed. The following are some of the observations:-

1) Food supplied in the hostels has enough nutrition and calorific values.

2) Both vegetarian and non-vegetarian food are cooked in a common mess. Meat supply to the hostels is by contractors. Meat animals are slaughtered in the mess premises. No prior examination of the animal or the meat is carried out.

3) Disinfectants are not used for cleansing vegetables before their use in cooking. Washing the vegetables in water is the common practice.

4) General cleanliness of clothes, finger nails are not observed by the cooks and bearers. The dormitory in which the mess workers reside is congested and unclean.

5) Enough clothing for these employees are not provided with the result that the dirty clothes are worn for weeks.

6) Facility for cleaning the utensils in warm water with disinfectants is provided.

7) Every hostel has a canteen, where the cleanliness is very poor. Snacks prepared in these canteens are not subject to any inspection during any time in a year. There is a great possibility of students contracting diseases by eating food, snacks at these places.

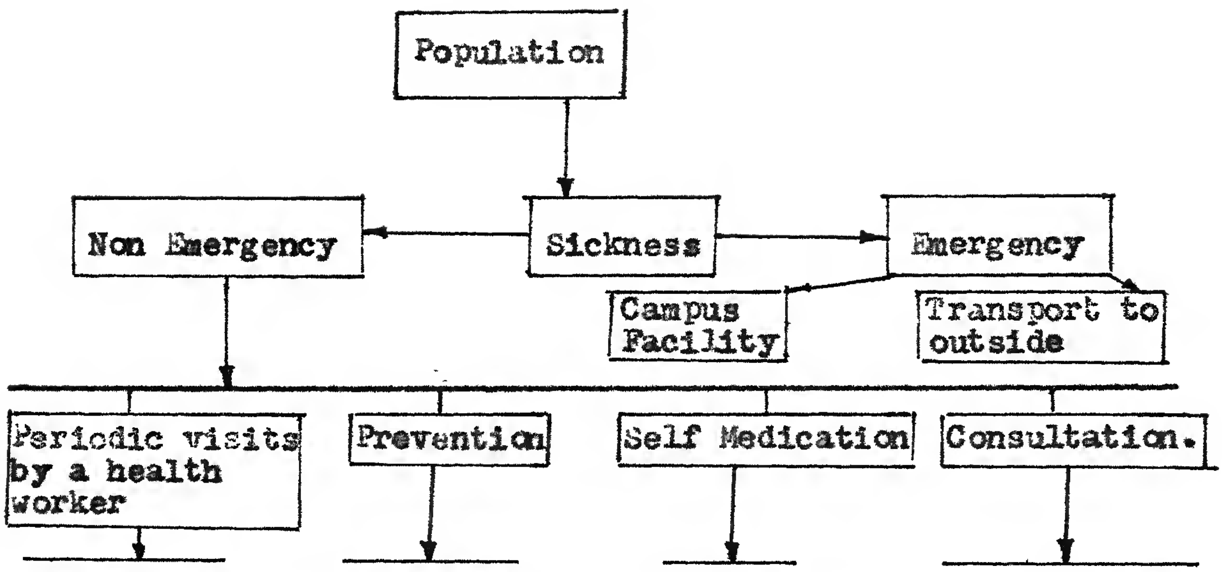
The information mentioned above give us an overall idea of the environment with which the health centre has to interact. Any solution to health delivery problem of the campus should be chosen keeping in mind the information gathered about the environment.

2.4 SYSTEM SYNTHESIS

2.4.1 The third phase of the methology in the systems approach is to evolve solutions to a social need. Hall (7) calls this as system synthesis. It is also called the preliminary design step of feasibility study (3). In this phase creativity for systems design is called for. Brain storming sessions are held to bring about several solutions to the problem. The brain storming sessions held in the present work had the participation of the following experts in addition to the author, and his co-worker.

1. Dr. Iqbal Krishan (Medical expert).
2. Dr. L.S. Srinath (Systems analyst).
3. Dr. V. Sundararajan.
4. Dr. H.V. Parameshwar.
5. Mr. Subramnya Shastri (co-worker).

The sessions brought forward the following alternative solutions given in the chart form:



Activities	Programs	Steps	Alternatives
1. Periodic visits to hostels and residences.	1. Immunization and Vaccination.	1. Self medication without any consultation.	1. Consultation on campus.
2. Treatment for minor ailments.	2. Sanitation.	2. Medication with remote consultation.	2. Outside consultation.
3. Notification of serious diseases to the consultant.	3. Health education.		3. Hired hospital.
			4. Medical arts centre.

All the four sub divisions under consultation are detailed as below:

1. Consultation on Campus.	2. Outside consultation	Hired hospital	Medical arts centre
a)Doctors' aide program. b)A full fledged consultant on the campus with medium type facilities and emergency cases being referred outside. c)All types of facilities.	a)Any consultant in the city with reimbursement of medical expenditure and transportation. b)Specified consultant in the city with all other facilities as in a.	a)A portion of a city hospital is hired by the Institute. Indoor and outdoor treatment are rendered in this hospital to Institute employees.	a)Allowing private practice by city physicians. b)Establishment of additional activity on medical sciences.

2.4.2 Feasibility of Solutions:

The feasibility of various alternatives suggested is presented below. This step is necessary to find out the feasible solutions so as to arrive at the best design alternative. Each alternative is worked out for the following details:

1. Organisation required.
2. Man power requirement.
3. Duties to be performed.

4. Work load on the personnel.

5. Qualifications and experience required.

and 6. Economic considerations.

These details for the alternatives mentioned above are given in Tables numbers 5 to 9. The conclusions drawn about each alternative is given below:

i) Health Workers' Program:

From the details of this alternative (Table number 6) it is seen that this alternative cannot be a complete solution. It may suit considerably as a part of some other alternative.

ii) Doctors' Aide Program:

Doctors' Aide Program as practised in U.S.A. seems to be a better alternative. This may be a centralised system or a decentralised system with offices at some key places on the campus. Advantages and disadvantages of both the types are presented in Table 7 from the details, it is concluded that this alternative alone is not a complete solution to our problem . This is the opinion of the medical expert also. The reasons for its incompleteness are

1. It does not have an accepted level of medical competance and qualification.

2. Long term illnesses, requiring intense care, cannot be treated on the campus.

iii) Full Fledged Consultant on the Campus:

The third alternative nearing the completeness of the solution, is to have a consultation centre on the campus

with full fledged consultants. The details of this alternative are given in Table 8. This alternative is a compromise between the sophisticated solution like a complete hospital and a health workers' program. Hence it is suggested that this alternative be combined with other programmes such as health worker, prevention and health education, to give a satisfactory system for the community's health problems.

iv) Other Alternatives:

The other alternatives arrived at earlier namely, Prevention, Self medication, Outside consultation, Hired hospital and Medical arts centre are found to be incomplete and economically unrealizable. A brief note on their incompleteness or economic unrealizability is given below:-

1. Prevention: This is not a complete solution because it does not have any curative programme. However, this forms a part of the final solution, for prevention is one of the efficient programs in reducing incidences of major illness.
2. Self medication: This also is an incomplete solution as it cannot be adopted in cases of complicated illness. Also knowledge of self medication is not common amongst all the individuals. Nevertheless, it is advantageous to disseminate the knowledge of self medication through health education programs. It is handy for minor illnesses and emergencies.

3. Outside consultation: From the discussions, it is concluded that outside consultation program is infeasible because,

a) It leads to extravagancy on medicines as the outside consultant can prescribe costly drugs.

b) A fleet of vehicles has to be operated from the campus to the outside consultant.

c) It gives scope for misuse of reimbursement facility and transportation facility.

d) Long term illness and maternity cases cannot be treated.

4. Hired hospital: This alternative serves considerably well the requirements of the problem. In some cities, like Bombay, (In Bombay city organisations like Bhabha Atomic Research Centre, Richardson and Cruddoss have hired a portion of J.J. Hospital,) this type of system is adopted by many organisations. However, for the present problem, this alternative is not physically reliazable because,

1. The Kanpur city hospitals are always over crowded and the administration of these hospitals refuse to rent any portion of their hospitals.

2. Immediate care is not available to campus residents.

3. Because of location, transportation facility has to be maintained, which is costly.

4. Emergency cases requiring immediate care cannot be looked after.

5. Medical arts centre: This alternative envisages establishment of teaching, practising and research in the area of medical sciences, on the campus. It then takes care of the health care problems of the campus community. It gives a comprehensive solution but incorporates a number of other activities, which though are not necessary for health care delivery are extremely useful. The alternative is economically unrealizable for a community like I.I.T - Kanpur because of its unwieldy nature.

2.5 System Analysis:

The feasibility descriptions about various alternatives, mentioned in the previous section clearly indicate that none of the alternatives alone can be a complete solution to the health delivery problem. A satisfactory solution to the problem is a combination of the alternatives discussed above. It is suggested that the following combination of alternatives gives a reasonably good system:

1. A campus consultation centre with fullfledged consultants and support facilities.
2. An elaborate prevention programme incorporating health workers programme and
3. Periodical health education programme.

The first of these is described in detail in Table 5. For (2) it is recommended that the program be entrusted to a separate body so that the prevention programme be carried out

independently. Decisions regarding the periods and frequency of immunization, vaccination and other prevention programs need to be taken in consultation with the physicians and the medical officers on the campus. The health workers programme, incorporated, helps in giving constant advise on sanitation, hygiene and cleanliness. It also helps in evaluating the prevention program. In (3) it is recommended that health education programmes be carried out in collaboration with the governmental and charity organisations, working for the same. Literature display, films and demonstrations are to be arranged periodically to promote consciousness of good health.

The suggested feasible combination of alternatives mentioned above, resembles closely with the existing health care delivery system on the campus. It is to be noted that the best alternative is arrived at by consensus. To arrive at the same rationally, there is a need of modelling the system and collecting exhaustive information regarding the effect of changes in various variables of the system.

One such variable of the system is demand of various services. An attempt has been made to analyse demand of various services, in the present work. This basically is a micro level analysis which can help in analysing the system for the best alternative. A similar attempt has been made for waiting line problems in I.I.T. - Kanpur health centre, by the co-worker of the author (10).

TABLE 1

PROFESSIONAL SERVICES

Sl. No.	Name of the Position		Duties
I.	Physician		
	(i) No.	4	1. Attending to the patients in outdoor and indoor.
	(ii) Salary: i. SMO Rs. 1500/- per month ii. Dr.1 Rs. 1185/- per month iii. Dr. 2 Rs. 911/- per month iv. Dr. 3 Rs. 750/- per month		2. Attending to the emergency cases. 3. Visiting houses. 4. Supervising over the other supporting staff and preparing their duty schedule. 5. Inspecting drugs during purchase.
	(iii) Duty hours: 8.00 AM to 12.30 4.30 PM to 6 PM		
II.	Pharmacists		
	(i) No.	5	1. Preparing the mixtures for patients.
	(ii) Salary: Rs. 217/- per month.		2. Dispensing the drugs.
	(iii) Duty hours: 8.00 AM - 4 PM 4.00 PM - 12PM 12 PM - 8 AM		3. Keeping a record of medicines dispensed
III.	Nurses		
	(i) No.	6	1. Attending to the indoor patients.
	(ii) Salary Rs. 285/- per month		2. Administering the injections to the patients. (outpatient and inpatient)
	(iii) Duty hours 8 AM - 4 PM 4 PM - 12PM 12 PM - 8 AM		3. Keeping the admission records of the patients. 4. Attending to the labour cases.

TABLE 2

SUPPORTING SERVICES

Sl. No.	Type of job.	Duties
I	**House Keeping**	
	(i) 5 sweepers and 4 sweepresses.	1. Cleaning the corridors, toilets and rooms of the health centre.
	(ii) Salary Rs. 150/- per month.	2. Attending to the emergency patients referred outside and sometimes accompanying them in the ambulance.
	(iii) Duty Hours: 8 hours/day	
II	**Transport Services**	Duties of the Driver:
	(i) No. of Ambulance 1	1. Bringing the emergency cases to the health centre in ambulance.
	(ii) No. of Drivers 3	
	(iii) Salary: Rs. 285/- per month	2. Taking the patients referred to the city hospital.
	(iv) Duty Hours: 8 AM - 2 PM 2 PM - 8 PM 8 PM - 8 AM	3. Making ambulance bills for non-entitled patients. 4. Maintaining the Log-book.

TABLE 3

NON-PROFESSIONAL SERVICES

Sl. No.	Name of the Position	Duties
I	Receptionist	
	(i) No. 2 (ii) Salary Rs. 100/- per month (Honorarium) (iii) Duty Hours: 9.0 AM - 12.00, 4.30 PM - 6 PM.	1. Guiding the new patients for registration and preparing their files. 2. Attending to phone calls for appointments, public enquiries and ambulance service. 3. Maintaining the records of various clinics such as Infant and child case chest and physiotherapy.
II	Office Staff	
	(i) No. 2 (ii) Salary: Rs. 223/- per month (iii) Duty hours: 10.0 AM to 5 PM.	1. Preparation of bills for various items such as medical reimbursement, ambulance, non-entitled patients and visits. 2. Preparation of duty charts and no-due certificates. 3. Maintenance of leave records, attendance registers, personnel files and stationeries.
III	Store Keeper	
	(i) No. 1 (ii) Salary Rs. 246/- per month.	1. Keeping an account of the medicines purchased for the dispensary. 2. Maintenance of the Stores records for contingencies, surgical instruments and furniture.

TABLE 4

BUDGETARY INFORMATION

	1969-70 (Lakhs)	1970-71 (Lakhs)	1971-72 (Lakhs)
1. Personnel Budget	-	1.84	1.86
2. Cost of Medicines and Reimbursement	2.05	2.75	3.00

TABLE 5

ANALYSIS OF CAMPUS WATER COMPARED WITH THE SPECIFICATIONS OF W.H.O.

W.H.O. Specifications.		Campus Water Analysis	
Characteristics	Concentration	Characteristics	Concentration
Lead	0.05 mg/l.	Total solids	740 mg/l.
Arsenic	0.05 mg/l.	Total Hardness	174 mg/l.
Selenium	0.01 mg/l.	Total alkalinity	480 mg/l.
Chromium	0.05 mg/l.	Calcium	140 mg/l.
Cyanide	0.20 mg/l.	Bicarbonates (calcium)	480mg/l.
Cadmium	0.01 mg/l.	Iron	0.28 mg/l.
Barium	1.00 mg/l.	Nitrates	3.1 mg/l.
Fluorides	1.00 mg/l.	Sulphates	13.8 mg/l.
Nitrates	45 mg/l.	Chlorides	60 mg/l.
		Fluorides	1.3 mg/l.

Standard interval of Testing.

Population upto 20,000

one sample/5000 population/month

Ref. International standards for Public Health, W.H.O. Publication.

TABLE 6

HEALTH WORKERS' PROGRAMME

Qualifications and experience	Manpower required	Duties and work load	Cost estimation	Remarks
1. State registered nurse, or a state certified midwife.	3 male and 2 Female nurses	1.Periodical house visits for health inquiry.	1.Salary of the staff at Rs.400/- P.M. Total = 2000/-	This alternative does not form a complete solution to the problem. The reasons are:
		2.Follow up of illness.		
2. Diploma in Nursing.		3.Identification and notification of major illnesses to specialist.	2.Medical kit Rs. 3147/- Total Rs.5147 P.M. Yearly total Rs.61,764/-	1.It lacks medical competance.
		4.Anti natal and Post natal care.		2.Emergency and long illnesses are to be referred outside.
		5.Evaluation of hygience, nutrition and sanitation.		
		6.Advising on cleanliness and sanitation.		3.Indoor facility is not provided.
		8 hours a day.		4.Maternity problems cannot be handled.

[redacted]

TABLE 7

DOCTORS' AIDE PROGRAM

Qualifications and experience:

1. A Diploma in medical science with experience in treating patients.

Man Power required:

1. Six Doctors' aides.
2. A helper.
3. A pharmacist.
4. A clerk.

Duties and Work Load:

1. Routine jobs:
   a) Attending to patients.
   b) Dressings and minor surgeries.
   c) Referring to outside for major illnesses.
   d) House visits.
   e) Pathological tests.
2. Emergency cases on rotation.
3. Transport supervision of ambulances.
4. Maintaining medical records.

Cost Estimation Per month:

1. Salaries

a) Salary of D.A. @ Rs. 500/- P.M.	Rs. 3000/-
b) Supporting staff @ Rs. 200/- P.M.	Rs. 600/-
c) Medical kit P.M. Rs. 3147 Total/m	Rs.6767/-

Yearly total Rs. 81,204/-

Cost of Medical accessories is excluded.

contd...

Remarks:

This alternative is a better one compared to health worker's programme.

Advantages and Disadvantages of a Centralised System:

Advantages:

1. Reduces cost of maintaining personal staff.
2. Quick results of pathalogical tests made available to doctors.
3. Centralised drug storage, thus reducing pilferation and wastage.
4. Requires one set of costly equipments only.

Disadvantages:

1. Over crowding of patients and hence noisy atmosphere.
2. Long waiting lines.
3. Because of over crowding, each patient gets less attention.
4. Long approach distances.

Advantages and Disadvantages of a Decentralised System:

Advantages:

1. Less crowding and hence peaceful atmosphere.
2. More time available for each patient for consultation.
3. Easily approachable.
4. Short waiting lines.

Disadvantages:

1. Additional equipment cost.
2. Increased staff.
3. Each unit cannot be provided with lab facilities hence lack of immediate information.
4. Greater scope for wastage and pilferage.

TABLE 8

A FULL FLEDGED CONSULTATION CENTRE ON THE CAMPUS

Qualification and Experience:

1. Doctors: M.B.B.S. with experience as a physician.
2. Pharmacist: Diploma in pharmacy.
3. Pathologist: Certificate holder in pathology labs.
4. Nurses, Dressers, Midwives: Matriculates with training in nursing.

Man Power Requirement:

1.	Doctors	5
2.	Pathologist	1
3.	Pharmacists	3
4.	Dressers	3
5.	Nurses	5
6.	Midwives	3
7.	Clerk	1
8.	Sweepers, Wardboys and Ayahs	10
9.	X-Ray Operator	1

Duties and Responsibilities with Work Load:

1. Daily attendance to patients, with examination, and prescription of medicines.
2. Attendance to Emergency cases brought to the Office and to calls from the residences.
3. Advicing management on purchases of medicines, etc.
4. Organizing immunizations, special clinics and health education programs.

contd....

5. Training the staff for advanced work 6 hours/day.

Support facility:

1. Consultation Offices.
2. Pharmacy.
3. Phathalogy Lab.
4. Impatient Ward.
5. Orthopediacs and gynaecology specialisation.
6. Injection and dressing rooms.
7. Transport facilities for referance to outside specialists.
8. Business office and office equipment.
9. Labour room.
10. Reservation of two beds in the city hospital for specialised and long treatment.
11. X-ray facility.

Cost Estimation:

1. Salaries of Doctors @ Rs. 1000/- P.M. = 5000/-
2. Salaries of supporting staff:

i.	Pathalogist:	Rs. 250/- P.M.
ii.	Pharmacist:	Rs. 250/- P.M.
iii.	Dresser:	Rs. 200/- P.M.
iv.	Nurse:	Rs. 250/- P.M.
v.	Midwife	Rs. 200/- P.M.
vi.	Clerk	Rs. 300/- P.M.
vii.	Sweepers, wardboys, etc.	Rs. 150/- P.M.
viii.	X-ray operator	Rs. 200/- P.M.

Yearly total Rs. 1,22,400/-

contd....

3. Cost of Medicine Rs. 37,750/- p.a.

Grand total Rs. 1,60,150/- p.a.

Cost of medical accessories excluded.

Remarks:

This solution meets most of the requirements of health delivery problem. All the disadvantages like low level of medical competance, lack of specialization and facilities of other solutions are overcome in this solution. However, this alone does not form a satisfactory solution to the problem. It is suggested that a combination of this solution with other programs like health workers program, preventive program forms a satisfactory solution.

TABLE 9

FINAL SOLUTION SUGGESTED

Name of the Part:

1. Campus consultation centre.

Man Power:

1.	Doctors	5
2.	Pathologist	1
3.	Pharmacist	3
4.	Nurses	5
5.	Dressers	3
6.	Midwives	3
7.	Sweepers, Wardboys and Ayahs.	10
8.	Clerk	1
9.	X-ray operator	1

Duties and Responsibilities:

1. Doctors

Duties and responsibilities as described in table 8.

2. Pathologist, Pharmacist and Nurses:

Their duties include their own professional work and an emergency call to do medical work outside their profession.

3. Dressers and Midwives:

Duties same as in item 2 above.

4. Clerk:

He should be able to manage business correspondance, preparation of bills for reimbursement and maintaining official records.

contd....

[redacted]

<u>Additional Facilities to be Provided:</u>

1. Quick transport facilities for emergency cases requiring hospitalization in the city.
2. A sepcialist in the city hospital hired on part time basis
3. Ambulance service for the Campus - Transport for patients who are seriously ill.

<u>Cost Estimation:</u>

1. For item numbers 1 to 9 under Man power, details are given in table 8.

Yearly total	Rs.1,22,400

2. YearlyContract amount for the city specialist — Rs. 5,000 p.a.
3. Running cost of ambulance vehicles

per year @ 200 litres/month petrol	Rs. 3,600
Repairs	Rs. 1,000
	Rs. 4,600 p.a.
Yearly total	Rs. 1,32,000

<u>Name of the Part:</u>

2. Prevention Programme and health workers programme
3. Health Education

<u>Man Power:</u>

1. Prevention Incharge (1)
2. Health Workers (2)
3. Clerk (one)

Same personnel as in 2 above will administer this program also.

Contd.....

Duties and Responsibilities:

Prevention Incharge:

1. Conducts preventive programmes like immunization, vaccination, TABC, tetanus etc.
2. Maintains correspondence with the city preventive programme officials.
3. Administers the health education programme as mentioned in the Part 3.

Health Workers:

1. Duties as mentioned in their programme in Table 2.
2. Assist in health education programmes.
3. Prepare programmes for screening films on health and sanitation.
4. Keep liaison with similar organizations.

Facilities Provided:

1. An office with business equipment.
2. Film projectors, demonstration desks and other accessories.
3. Transport facilities.

Remakrs:

Cost analysis for these two programmes are not considered as sufficient cost information is not available.

CHAPTER 3

DEMAND ESTIMATION OF SERVICES

It was mentioned in Chapter 2 that system synthesis gives various alternatives to a design problem. For selecting the best alternative, exhaustive information about various alternatives is required. This can be obtained either from the statistical data of the existing systems or from a mathematical modeling of alternatives for important objectives. One such objective is that of demand estimation. The formulation not only helps in system design analysis but also can be used for improving the services of existing health centres.

3.2 FORMULATION OF THE PROBLEM

A stochastic model of the indoor process in a hospital has been formulated by Dr.Small wood (10). The model estimates the average demand of services and its variance from the stochastic model.

The present work is to formulate the problem of health - cure process for an out door patient department of IIT-K Health Centre and those similar to it, suitable to treatment conditions in our country. Model for health cure process is also presented when a preventive programme is incorporated. A case study for demand estimation for IIT - K Health Centre is undertaken.

3.3 FORMULATION

Maintaining good health is closely related to immunity to most of the prevalent diseases. Still the community may be badly affected due to certain diseases. The pattern of these diseases, the medical treatment and the process through which a patient has to undergo before getting cured, needs explanation. Some technical terms are involved which are explained below.

i. Arrival Pattern

Diseases in general occur randomly and advance in a random manner depending on the individuals immunity to such occurrences. Once the level of disease reaches a threshold, the patient seeks medical help. This constitutes the arrival process.

ii. Disease Dynamics and Symptom Dynamics

Patient enters the facility with the initial level of disease. Physician after examining the patient and diagnosing the disease wherever possible prescribes certain medicines. The patient is thus put in his initial state of the disease. There after the patient moves from state to state with the medical treatment. In every state the physician prescribes different services depending on the patient's progress. The movement from state to state is a random process. The patient moves to the next state from his present state with a transition probability, after residing for some time in his present state. Thus the process is semi-Markovian, with discrete time and discrete states. (Figure No. 2).

Diseases are classified according to an international standard (13). Identification of diseases according to this

standard requires complete diagnosis, which is not always possible. Especially in many cases in out door treatment, complete diagnosis is invariably not possible because of short time for patient examination. Also in developing countries like India, facilities for immediate tests and communication of results of the tests are not present in many hospitals. Hence some-times, treatment is based on symptoms. A group of symptoms is identified which pertain to major systems of the body like nervous system, liver system and abdominal system. A symptom dynamics exists in this case and the patient moves from state to state of his symptom dynamics, with the medical treatment. It is similar to the disease dynamics and is semi - Markovian in nature.

iii. Care elements

When the patient is in a state, the physician prescribe some services for the medical care of the patient, like, X-ray, path logical tests, medicines, indoor admission etc. These services are ordered depending upon the level of disease of the patient and to some extent, the practice followed by the physician. The latter varies from physician to physician. Thus the demand for the care elements is another stochastic process.

3.3.1 The Models

Having described the technical terms, the whole process of treatment of illness can be represented in a block diagram as shown below. Three models are considered for demand estimation. They are :

a. Model for the treatment based on disease dynamics

b. Model for the treatment based on symptom dynamics

c. Combined treatment on both disease and symptom dynamics.

i. Model for treatment on disease diagnosis (Figure No. 3)

In this model the following are the definitions of various quantities:

$\alpha_i(n)$ = Number of patients entering the facility on any day n with disease i

n_k^i = Number of patients who occupy k^{th} state of disease, i, on any day.

d_{km}^i = Number of care elements of type 'm' required by a patient in the k^{th} state of disease 'i'.

As mentioned earlier, the disease dynamics follows net work of discrete states, discrete time semi-Markovian process. The parameters of the semi-Markovian process are, (Figure No. 2).

p_{jk}^i = Probability that a patient in j^{th} state of i^{th} disease will next transfer to k^{th} state of the same disease.

$h_{jk}^i(n)$ = Probability that a patient who has just entered the j^{th} state of disease i, will stay exactly 'n' days before entering state k.

ii. Model for treatment on symptoms. (Figure No. 4)

In this model the following are the definitions of various quantities:

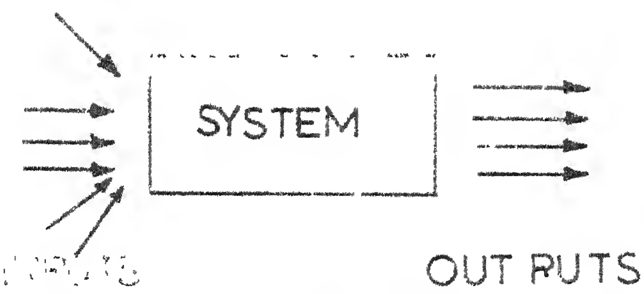
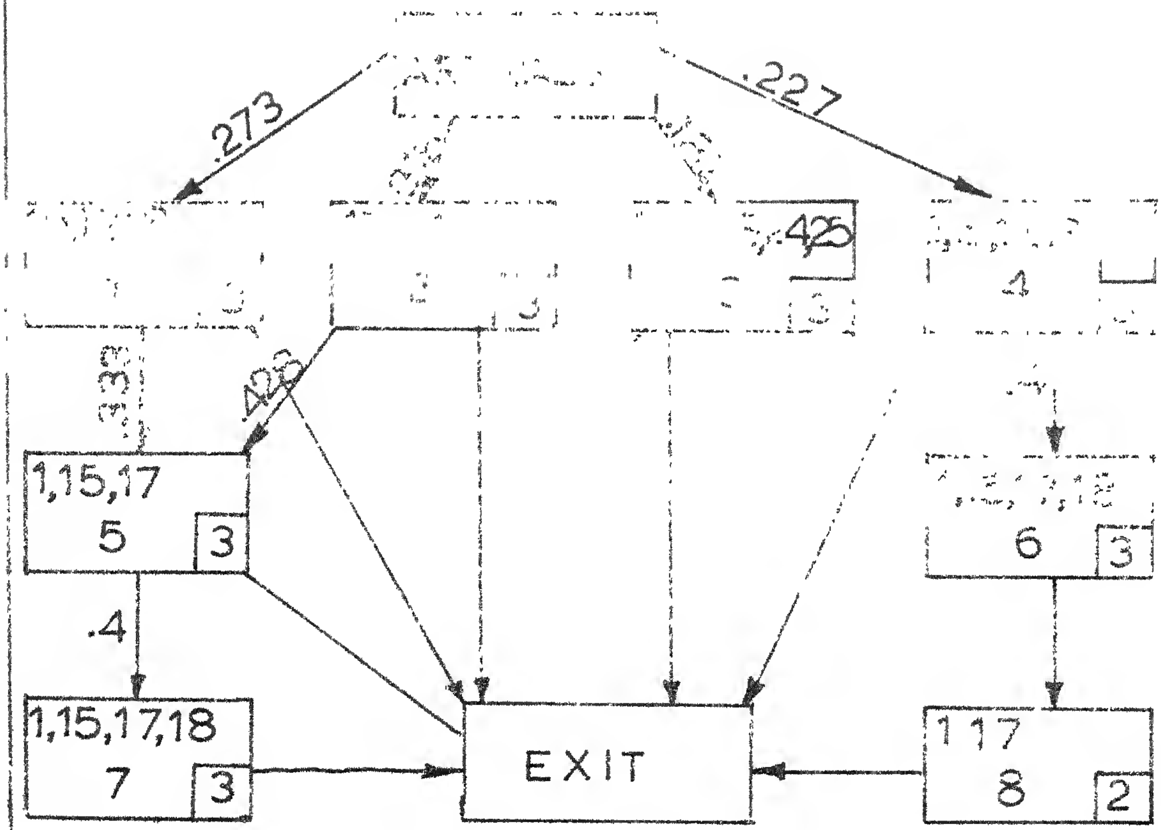


FIG. I. SY[illegible] & ENVIR[illegible]NT



Index.

1. Numbers on arrows indicate Transition Probabilities
2. Numbers at the bottom right corner are stay Periods
3. Other Numbers are State identifying numbers, at the middle of blocks.
4. Numbers at the top of the block are care elements.

FIG. 2. DISEASE DYNAMICS.

FIG. 3. MODEL 1

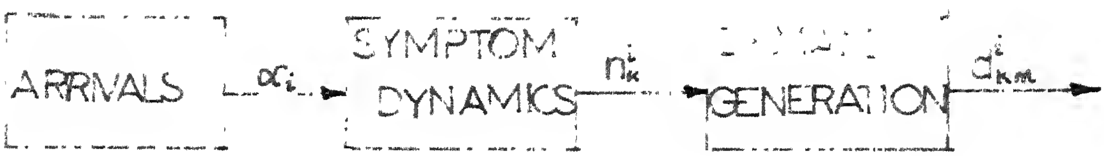


FIG. 4. MODEL 2

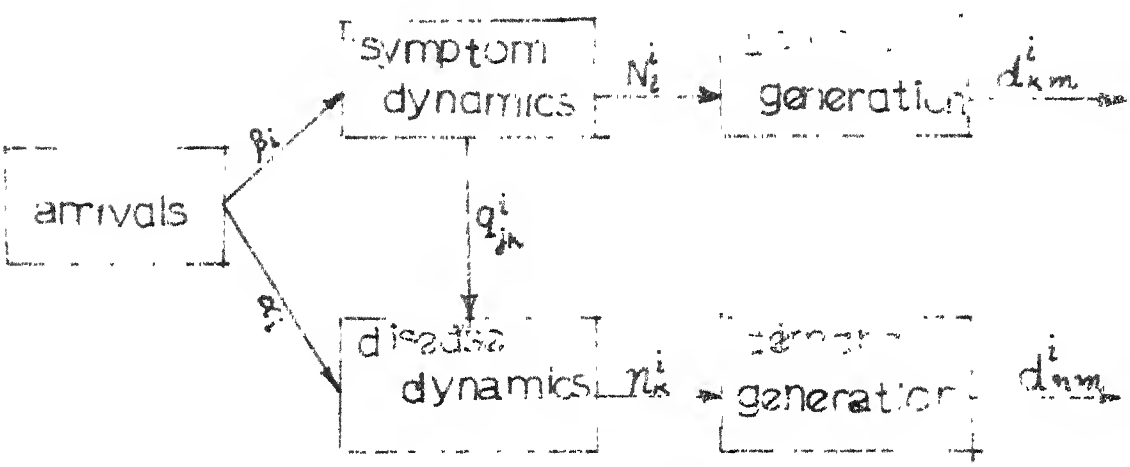


FIG. 5. MODEL 3

are defined for convenience of derivation of results.

1. μ_k^i = Number of days a patient spends in k^{th} state of i^{th} disease (wherever disease is mentioned the definition applies also to the symptom group).

2. V_k^i = Number of days that two patients stay in state k of disease i, both having arrived at the facility on the same day.

3. V_{jk}^i = Number of days that a patient in j^{th} state of disease i, stays in that state simultaneously with another person in state k of disease i. Expressions for all the three variables mentioned above, in terms of the semi - Markovian parameters are derived in Appendix 1.

3.4.1 PATIENT CENSUS

The patient census n_k^i is defined as the number of patients residing in state 'k' of disease i. With the definition of μ_k^i, n_k^i is given by

$$\bar{n}_k^i = \bar{\alpha}_i \ \mu_k^i \tag{1}$$

where (-) is used to denote expected value .

The variance of $\bar{n}_k^i$ is measured as the expected difference in trajectory of $(\mu_k^i - V_k^i)$, Then

$$\text{Var}\ (n_k^i) = \bar{\alpha}_i(\bar{\mu}_k^i - \bar{V}_k^i) + \text{Var}\ (\alpha_i V_k^i) \tag{2}$$

Expressions for (1) and (2) as functions of time are derived using Semi - Markovian parameters in appendix 1.

For model iii, the equations (1) becomes

$$\bar{N}^i_l = \bar{\beta}_i \ \bar{U}^i_l \qquad \text{if } l \leqslant j \tag{3a}$$

$$= p^i_{jk} \bar{\beta}_i \ \bar{U}^i_l \qquad \text{if } l > j \tag{3b}$$

and $$\bar{n}^i_r = \bar{\alpha}_i \ \bar{\mu}^i_r \qquad \text{if } r < k \tag{4a}$$

$$= (\bar{\alpha}_i + q^i_{jk} \bar{\beta}_i) \ \bar{\mu}^i_r \qquad \text{if } r \geqslant k \tag{4b}$$

N^i_l denotes the patient census in state l.

U^i_l denotes μ^i_k in state l.

$$\text{Var}(N^i_l) = \bar{\beta}_i (\bar{U}^i_l - \bar{V}^i_l) + \text{Var}(\beta_i \ \bar{V}^i_l) \tag{5a}$$

if $l \leqslant j$

$$= p^i_{jk} \bar{\beta}_i (U^i_l - \bar{V}^i_l) + \text{Var}(p^i_{jk} \ \beta_i \ \bar{V}^i_l)$$

if $l > j$ (5b)

and $$\text{Var}(n^i_r) = \bar{\alpha}_i (\bar{\mu}^i_r - \bar{v}^i_r) + \text{Var}(\alpha_i \ \bar{v}^i_r) \tag{6a}$$

if $r < k$

$$= (\bar{\alpha}_i + q^i_{jk} \bar{\beta}_i)(\bar{\mu}^i_r - v^i_r) + \text{Var}(\alpha_i + q^i_{jk} \beta_i)(v^i_r)$$

if $r \geqslant k$ (6b)

where v^i_r denotes V^i_k in state r

Expressions for (1) & (2) as functions of time, are derived in terms of semi - Markovian parameters in Appendix 1.

[redacted]

3.4.2 DEMAND GENERATION

The second quantity of importance is the average demand of various services. For models (i) and (ii), this can be written in terms of the variables μ^i_k, α_i and d^i_{km} which have been defined earlier. Denoting $\bar{D}_m$ as the average demand of type m,

$$\bar{D}_m = \sum_i \bar{\alpha}_i \sum_k \bar{\mu}^i_k . \bar{d}^i_{km} \qquad (7)$$

The variance of D_m is given by

$$\mathrm{Var}\,(D_m) = \sum_i \Big\{ (\mathrm{Var}\,(\alpha_i) - \bar{\alpha}_i) \sum_{j,k} V^i_{jk} . \bar{d}^i_{jm} . \bar{d}^i_{km} + \alpha_i \sum_k \mu^i_k . \overline{d^{i\,2}_{km}} \Big\} \qquad (8)$$

where $\overline{d^{i\,2}_{km}}$ is the mean square demand of type 'm' in k^{th} state of disease i.

For model iii, expression (7) becomes

$$\bar{D}_{sm} = \Big(\sum_i \bar{\beta}_i \sum_{l=1}^{j} \bar{U}^i_l . \bar{d}^i_{lm} + \delta_j \sum_{i,j} p^i_{jk} . \bar{\beta}_i \sum_{l=j+1}^{M1} \bar{U}^i_l . \bar{d}^i_{lm}\Big) \qquad (9a)$$

where $\delta_j = 1$ if $M1 \geqslant j$, $\delta_j = 0$ if $M1 < j$.

M1 = Number of states for symptom group.

M2 = Number of states in the disease.

And

$$\bar{D}_{dm} = \Big(\sum_i \bar{\alpha}_i \sum_{r=1}^{k-1} \bar{\mu}^i_r . \bar{d}^i_{rm}\Big) + \Big(\sum_i \bar{\beta}_i . q^i_{jk} \sum_{r=k}^{M2} \bar{\mu}^i_r . \bar{d}^i_{rm}\Big) \qquad (9b)$$

[redacted]

Expression (8) becomes

$$\mathrm{Var}\,(D_{sm}) = \sum_i \Big\{(\mathrm{Var}(\beta_i) - \bar{\beta}_i) \sum_{s,l} V^i_{sl}\, \bar{d}^i_{sm} \cdot d^i_{lm} +$$

s,l from 1 to j

$$\sum_l U^i_l\, \bar{d}^{i2}_{lm}\Big\} + \delta_j \sum_i \Big\{(\mathrm{Var}\,(p^i_{jk}\beta_i) - p^i_{jk}\bar{\beta}_i).$$

$$\sum_{s,l} V^i_{sl}\, \bar{d}^i_{sm} \cdot \bar{d}^i_{lm} + U^i_l\, \bar{d}^{i2}_{lm}\Big\} \qquad - \qquad (10a)$$

s,l from j+1 to M1

and

$$\mathrm{Var}\,(D_{dm}) = \sum_i \Big\{(\mathrm{Var}\,(\alpha_i) - \bar{\alpha}_i) \sum_{r,x} v^i_{rx} \cdot \bar{d}^i_{rm} \cdot d^i_{xm}$$

r,x from 1 to k-1

$$+ \sum_r \mu^i_r\, \bar{d}^{i2}_{rm} + \sum \Big\{\Big[\mathrm{Var}\,(\alpha_i + q^i_{jk}\beta_i) - (\bar{\alpha}_i + q^i_{jk}\bar{\beta}_i)\Big] \cdot$$

$$\sum_{r,x} (v^i_{rx}\, \bar{d}^i_{rm} \cdot \bar{d}^i_{xm}) + \mu^i_r\, \bar{d}^{i2}_{rm}\Big\} \qquad - \qquad (10b)$$

r,x from k to M2

Expression for (7) and (8) in terms of semi-Markovian parameters and as functions of time are derived in Appendix 1.

3.4.3 Preventive Program:

When a preventive program is employed in reducing the number of incidences of certain diseases, it is possible to ascertain, by statistical methods the percentage to which the program has been effective.

If x_i is the percentage successfulness of a preventive program for disease i, the patient inflow to the health facility gets reduced by this factor. In the expressions for patient census and average demand, α_i the earlier patient inflow, when the preventive program was not in operation, is to be replaced by $(1-x_i)\,\alpha_i$. The expressions, then, give the expected load, taking into consideration the effect of preventive program.

[redacted]

CHAPTER 4

SAMPLE DATA COLLECTION AND RESULTS

It is mentioned in Chapter 3 that three models can represent an out door department of health centre but only the first one is tested for its suitability in the present work by collecting sample data from the I.I.T. Kanpur Health Centre. This involves,

a) Selecting the most prevalent diseases,

b) Establishing disease dynamics for the selected diseases and

c) Selecting the care elements.

Formats are designed to collect relevant data for all these diseases. For the data collected the results are computed on IBM 7044 computer. Steps involved are detailed below.

4.2 Study of the Experimental Station

With a view to design the experiment for data collection, the patient inflow in the Health Centre - out door, through various service counters, is described diagrammatically in Figure 7.

4.3 Selection of Diseases

For the purpose of sample data collection, diseases are selected on the following basis.

[redacted]

1. Commonly prevalent diseases which cause maximum load on the health centre.
2. Diseases for which disease dynamics can be established with all the possible details.
3. Dimensions of the experimental work and the available man power for data collection and
4. Level prediction of the disease with simple diagnosis.

In a series of discussions with the physicians on the Campus, the objectives of the study were explained to them, and the final list of diseases is decided on the basis of consensus. Originally the list contained 25 diseases but was reduced to 10, listed in Table 10, because of the dimensions of the experimental work and the limited available personnel help.

4.4 Selection of Care elements

As explained in 3.2, every state in the curing process is defined by three parameters. These are the transisition probability, stay period and a set of care elements demanded by the patient during his stay in that state. In the Health Centre, the service counters in the autdoor department are:

1. Physicians
2. Pharmacy

3. Dressing room

4. Injection room

5. Phathology Lab.

The care elements have been chosen as the services rendered in these counters. The list of care elements used in the experiment is given in Table 12.

4.5 Establishing Disease dynamics.

The disease dynamics for all the diseases chosen is based on interviews with the physicians. The data collection is planned so as to bring out the disease dynamics, number of repeated visits, and the care elements demanded.

4.6 Design of the experiment for sample data collection.

4.6.1 Data Collection Form.

The data collection form gives the list of the diseases, care elements and proper instructions to the servicemen. A copy of the form is attached at the end of this Chapter. The data is collected for a period of 15 days.

4.6.2 Disease dynamics from the data forms.

In each form the following entries are made:

1. Diagnosis of the disease
2. Care elements serviced to the patient and
3. Date of examination

From a set of data forms of the same disease different states are identified by grouping the sets of care elements which are different for different states. The stationary probabilities are calculated by dividing the number of patients in a state by the total number of patients in the previous state from which the transition was made to the present state. The disease dynamics is obtained by identifying these states for repeated visits of the patients. The disease dynamics for the selected diseases is given in Figure 6.

4.6.3. Other data.

Additional data on daily incidence rate of the diseases under consideration, mean and mean square values of the daily dosages of services of each type for all the ten diseases are collected. The former from the Health Centre records and the latter from physicians' opinion. These are given in tables 11 and 12 respectively.

4.7 Computation and results.

The outputs of the model, namely averages and variances of demand of services are computed. The patient inflow is assumed to be of poisson distribution with average equal to the variance (10). A sample calculation of these quantities is given in Appendix 2. The results from the model are tabulated along with the daily demand of various quantities in table 13.

[redacted]

DATA COLLECTION FORM

(For Instructions Please turn over)

Patient Name Bisan File No. 283

1. Dysentry & Di

2. Boil & Carbun

CARE ELEMENTS

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7.6.72						3			3	3										
12.6.72							4		4	4										

INJ — DRESSING — PHARMACY — PATHOLOGY — X-RAY

CHAPTER 5

DISCUSSION AND CONCLUSION.

SYSTEMS APPROACH TO HEALTH CARE DELIVERY PROBLEMS.

In the second chapter, the systems approach to the design of health care delivery systems was presented. First many alternative solutions were evolved and with the feasibility study, the best alternative is chosen. The suggested solution is close to the existing system and only some parts of the solution are to be incorporated in the existing system to make it complete. In fact some of the aspects of suggested health education programmes are already in use in the form of Baby Clinic, meetings of Women's association. It is suggested that unification of all these activities be brought under one administration.

From the results of the demand estimation model for the sample data collected, the following observations can be made. The distribution of quantities of medicine from the model has a resemblance to that of the actual consumption. In case of services like injection, the values obtained from the model are satisfactory.

The results obtained for the services in the Pharmacy counter are much larger in magnitude than the actual consumption (table 13). In case of pathology tests the results from the model are relatively very low. Comparable resemblance exists only in the case of Pharmacy section.

The discrepancies between the results of the model and actual consumption are largely due to the inaccuracies in establishing disease states, transitional probabilities and the patient inflow data. The disease dynamics for every disease is not clearly brought out from the data forms because the patients visit the health centre invariably once only, and there will be only a few number of patients who will complete the disease dynamics. The transitional probabilities calculated from the repeated visits of these patients result in their increased values which lead partly to wrong identification of the states.

Whereas the model is applicable only to patients with new case, the exact inflow of new cases is not recorded in the health centre. This is one of the reasons for appreciable difference in the results calculated from the model and the actual data.

CONCLUSION

From the present study, involving systems approach to health care problems at local level, it has been established that the methodology is quite powerful. A group of Industrial

Engineers in consultation with the medical experts have arrived at the system which resembles closely the system designed by experienced medical experts. Since this is true for a local health centre, it will be true for the design of regional health delivery systems and to the problem of adopting National health policy. In the opinion of the author, the methodology is powerful enough to lead to optimal solutions of health delivery problem which meet the social needs.

It has been substantiated that the demand estimation of services of a local health delivery system can reasonably be modelled. The results can be improved considerably by taking data over much longer period and identifying the disease dynamics, care elements etc. It implies that even though health delivery systems are quite complex and not easily ame-nable to mathematical formulations approximate results of various quantities can be obtained by adopting a stochastic process model, depicting the complete curing process of diseases. The model for which data is collected from a local health centre gives results which will be applicable to all the health centres of simlar nature. Similar formulations can be done for complex health delivery systems which will help in improved design and performance of such systems.

[redacted]

TABLE 10

LIST OF DISEASES SELECTED

1. Dysentry and Diahorria
2. Boil and carbuncle (Infected)
3. Conjuctivitis and Opthalmia
4. Laceration and open wounds (non infected)
5. Cough (other than T.B.)
6. Viral Fevers
7. Prenatal care
8. Anemia
9. Hyper acidity
10. Tuberculosis

TABLE 11

DAILY INCIDENCE RATE OF DISEASES

1.	Dysentry and Diahorria	20
2.	Boil and Carbuncle	20
3.	Conjuctivitis and Opthalmia	10
4.	Laceration and open wounds	3
5.	Cough (other than T.B.)	35
6.	Viral Fevers	15
7.	Prenatal care	5
8.	Anemnia	5
9.	Hyper acidity	5
10.	Tuberculosis	0

[redacted]

TABLE 12

MEAN AND MEAN SQUARE VALUES OF DAILY DOSAGES OF CARE ELEMENTS.

Sl. No. (1)	Name (2)	Care & element No. (3)	Mean (4)	Mean square (5)
	1. Dysentry and Dihorria:			
1.	Injections	1	1	1
2.	Unispasmin Tab.	2	3.5	12.5
3.	Sulpha guladine	3	16	256
4.	Thalazola	4	9	90
5.	Kaoline Mixture	5	303	9
6.	Enterio Vioform	6	7	50
7.	Furamide	7	6	36.0
	2. Boil and Carbuncle:			
1.	Injections	1	1	1
2.	Dressing	8	1	1
3.	Sulpha Ointment	9	10 gms	100
4.	Sulpha Diazine	10	8	64
5.	Sulpha Thalazola	4	7	50

contd...

[redacted]

(1)	(2)	(3)	(4)	(5)
	3. Conjuctivits and Opthalmia:			
1.	Injections	1	1	1
2.	Sulpha Ceteramide	11	9	80
3.	Ramplenicol	12	6	36
4.	Terramycin	13	6	36
	4. Cough:			
1.	Injections	1	1	1
2.	Cough sed mixt	14	3 oz.	9 oz.
3.	Aspirin	15	6	36
4.	C. Mallete	16	3	9
5.	R.B.C. Count	25	1	1
6.	Haeomoglobin test	26	1	1
7.	Total W.B.C.	27	1	1
8.	Differential W.B.C.	28	1	1
	5. Viral Fevers:			
1.	Injections	1	1	1
2.	Drapherate	17	3	9
3.	Aspirin	15	6	36
4.	Analgin	18	4.5	22.5
5.	R.B.C. Count	24	1	1
6.	Haemoglobin test	24	1	1

(1)	(2)	(3)	(4)	(5)
	6. Prenatal Care:			
1.	Injections	1	1	1
2.	Fersolate	19	3	9
3.	Multivitamin	20	1	1
4.	Ancoloxin	21	2	4
5.	Haemoglobin test	26	1	1
6.	Total W.B.C.	27	1	1
	7. Anemia:			
1.	Injections	1	1	1
2.	F.A.C.	22	3 oz.	9 oz.
3.	Fersolate	19	3.5	12.5
4.	Haematrin	23	3	9
5.	R.B.C. Count	25	1	1
6.	Haemoglobin test	26	1	1
	8. Hyper acidity			
1.	Injections	1	1	1
2.	Gelusil	23	3.5	12.5
3.	Enteriovioform	6	4.5	22.5
4.	E.S.R.	29	1	1
5.	Routine stool test	30	1	1

TABLE 13

RESULTS FROM THE MODEL TABULATED WITH ACTUAL DAILY CONSUMPTION.

Care element No. (1)	N A M E (2)	Daily average from the model (3)	Variance of demand from the model (4)	Actual average consumption per day (5)
1	Injection	208	208	110
2	Unispasmin	251.05	896.6	150.00
3	Sulpha guladine Tabs	694.94	11119.10	-
4	Thalazola Tab.	180.16	1801.6	-
5	Kaoline Mixture	204.83	614.5	-
6	Enterio Vioform Tabs.	444.67	3176.19	560
7	Furamide Tabs.	260.22	1561.32	-
8	Dressing	41.68	41.68	-
9	Sulpha ointment	234.6	2346.0	-
10	Sulpha diazine Tabs.	431.53	3452.25	-
11	Sulpha Ceteramide (eye drop)	352.82	3136.19	-
12	Rampienicol (eye drop)	93.60	561.00	-
13	Terramycin(eye drop)	48.00	288.00	-
14	Cough sed mixture	334.56	1003.68	-

[redacted]

(1)	(2)	(3)	(4)	(5) £
15.	Aspirin Tabs.	1172.86	7096.15	660.00
16.	C.Mallete Tabs.	373.30	1136.41	330.00
17.	Draphorate mixture	91.82	275.46	-
18.	Analgin Tabs.	220.89	1104.85	200.00
19.	Fersolate Tabs.	190.77	406.75	400.00
20.	Multivitamin Tabs.	43.50	43.5	-
21.	Ancoloxin Tabs.	80.00	160.00	-
22.	F.A.C. Mixture	46.26	138.78	-
23.	Gelusil	105.00	375.00	-
24.	Haematrin Tabs.	39.42	118.26	-
25.	R.B.C. Count	13.80	13.80	-
26.	Haemoglobin test	17.86	17.86	-
27.	Total W.B.C.	6.92	6.92	-
28.	Differential W.B.C.	0.0	0.0	-
29.	E.S.R.	5.0	5.0	-
30.	Routine stool test	5.0	5.0	-

FIG.6c. [illegible]

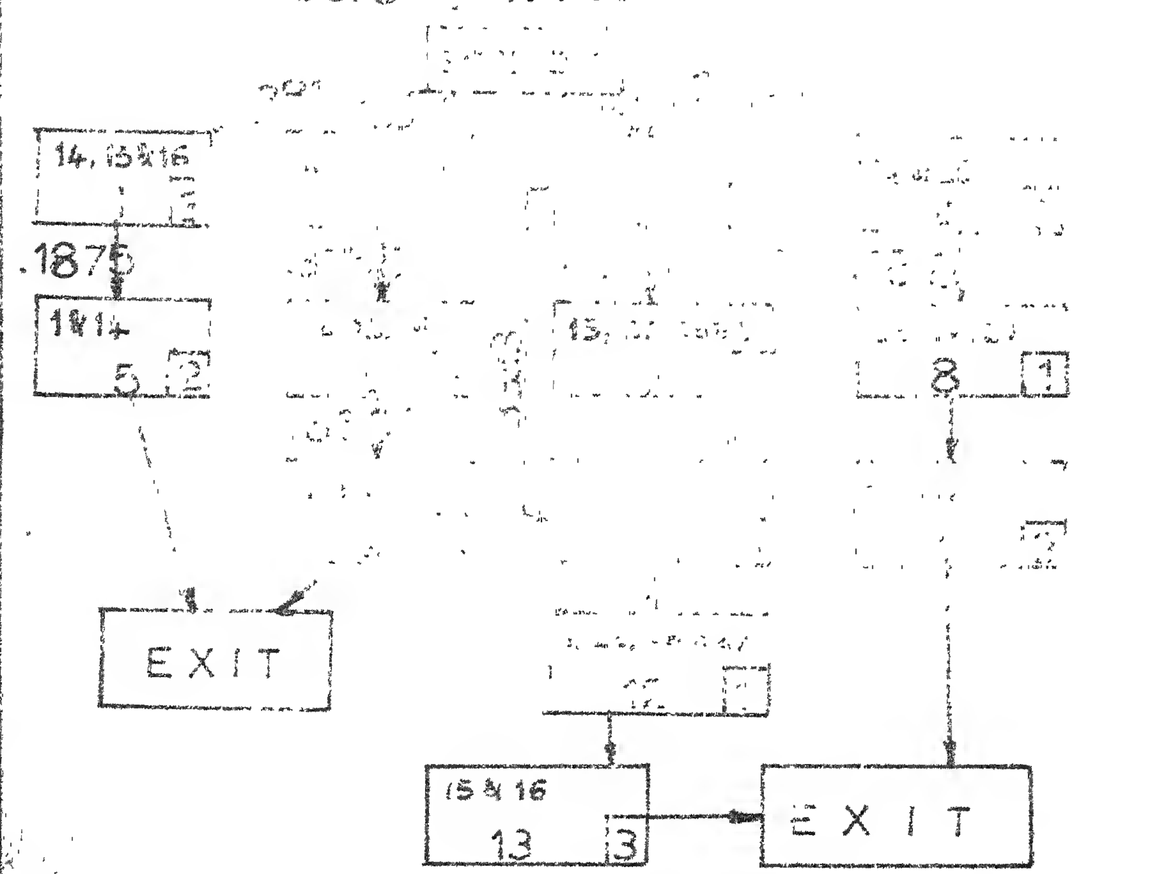


FIG. 6d. Cough

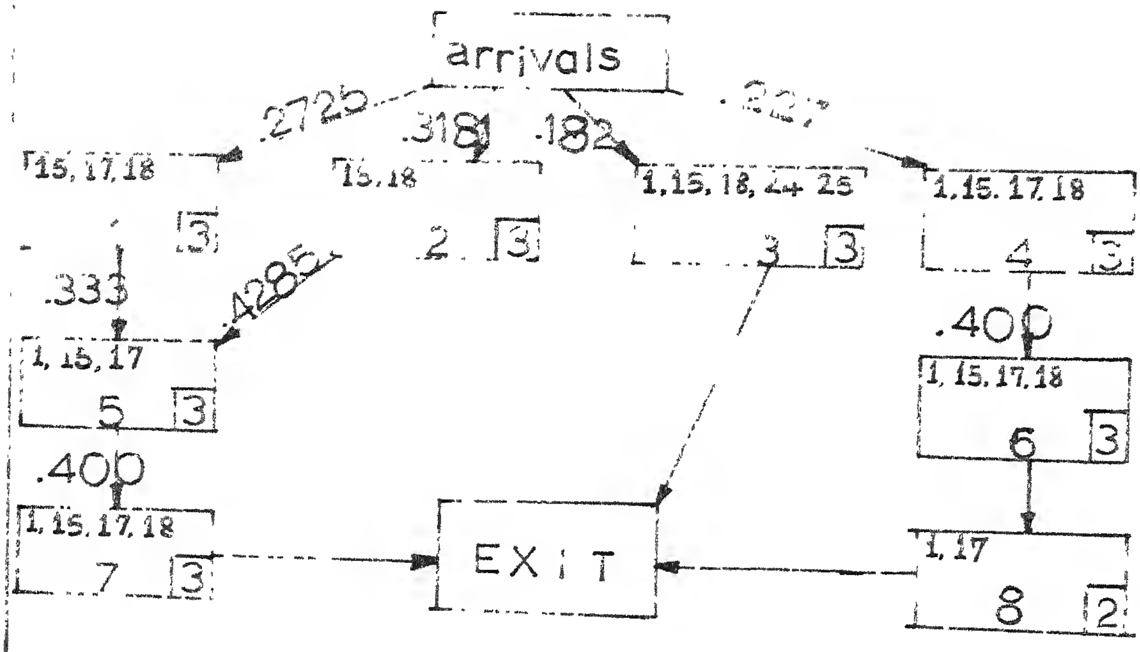


FIG. 6e. Viral fevers

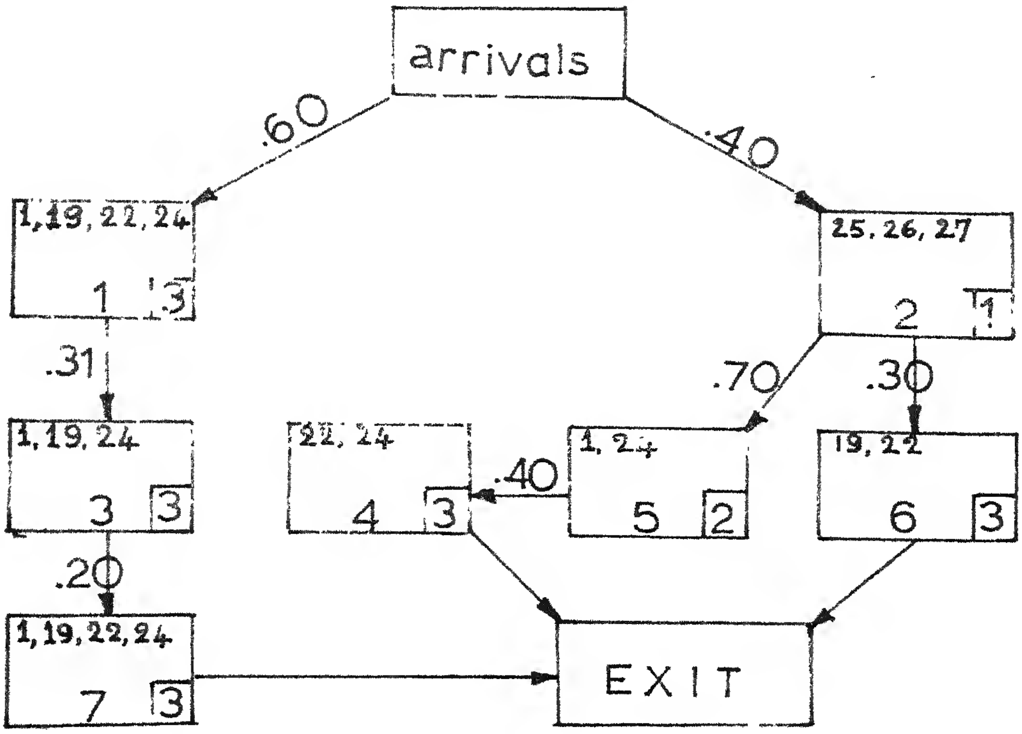


FIG. 6 f. Anemia

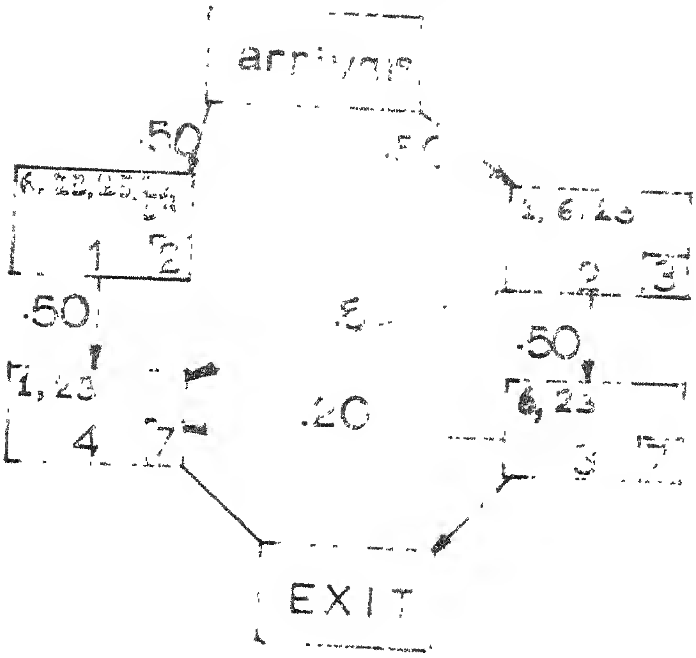


FIG.6h. Hyper Acidity.

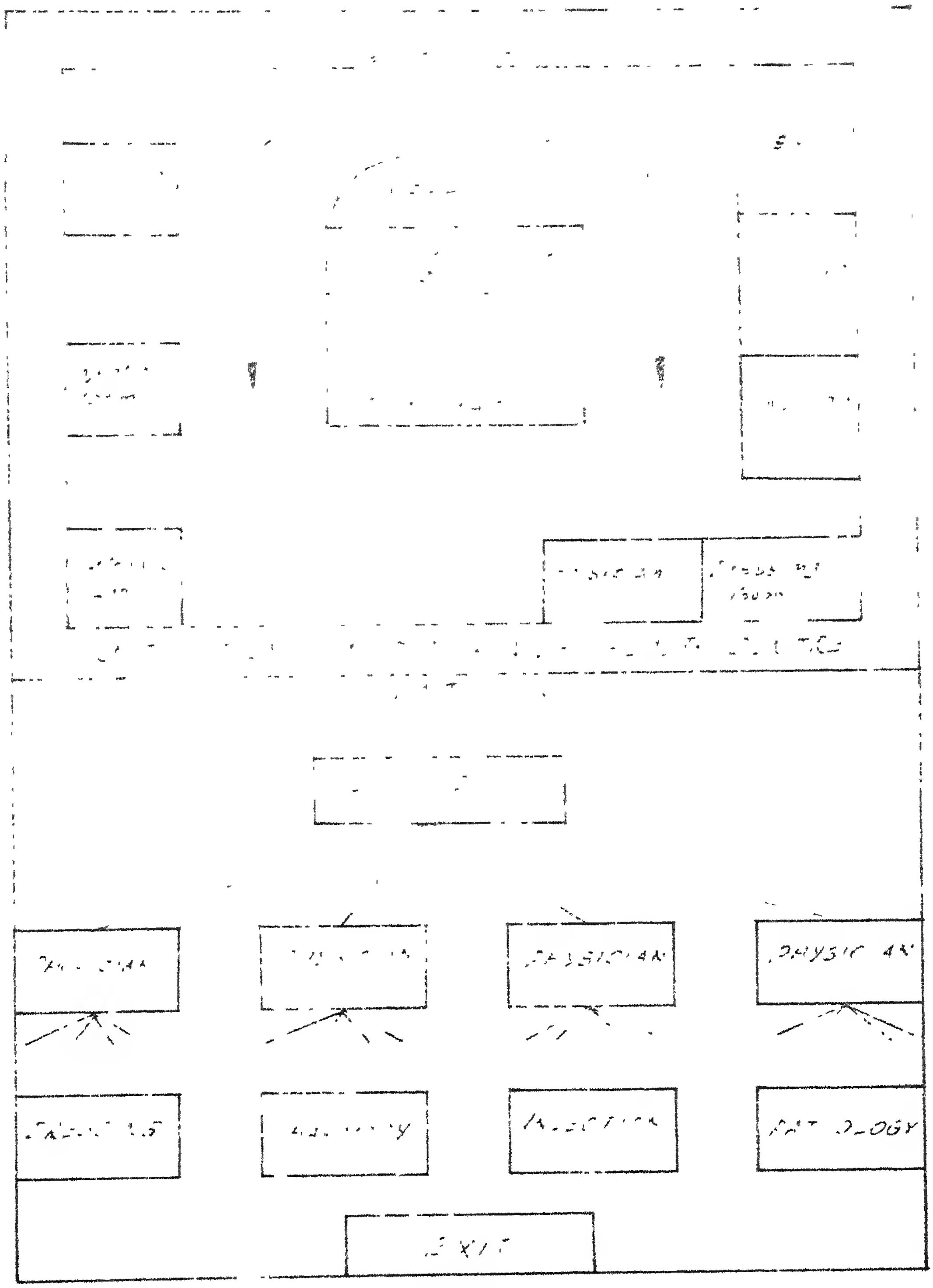
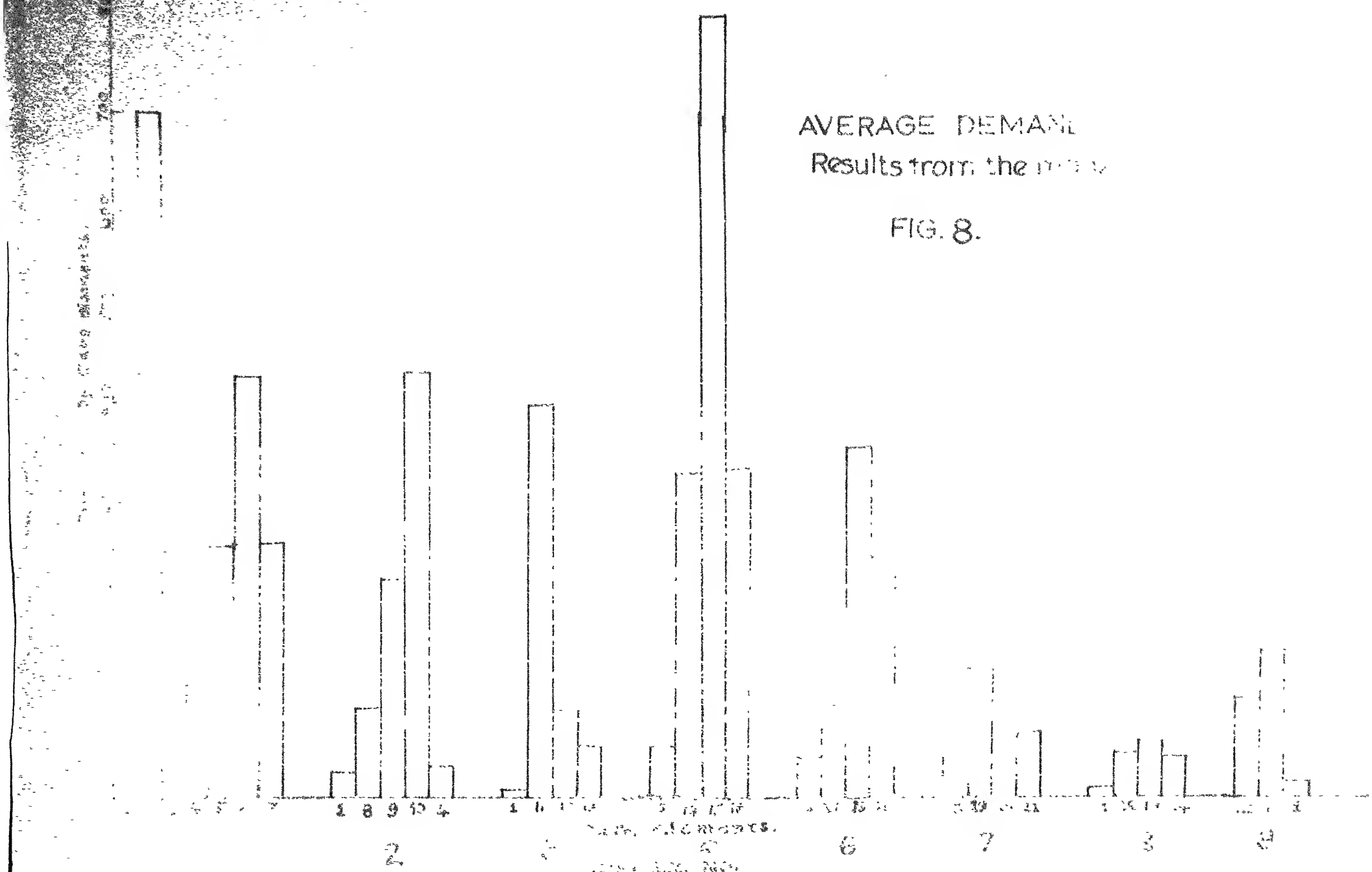


FIG. 7

AVERAGE DEMAN...

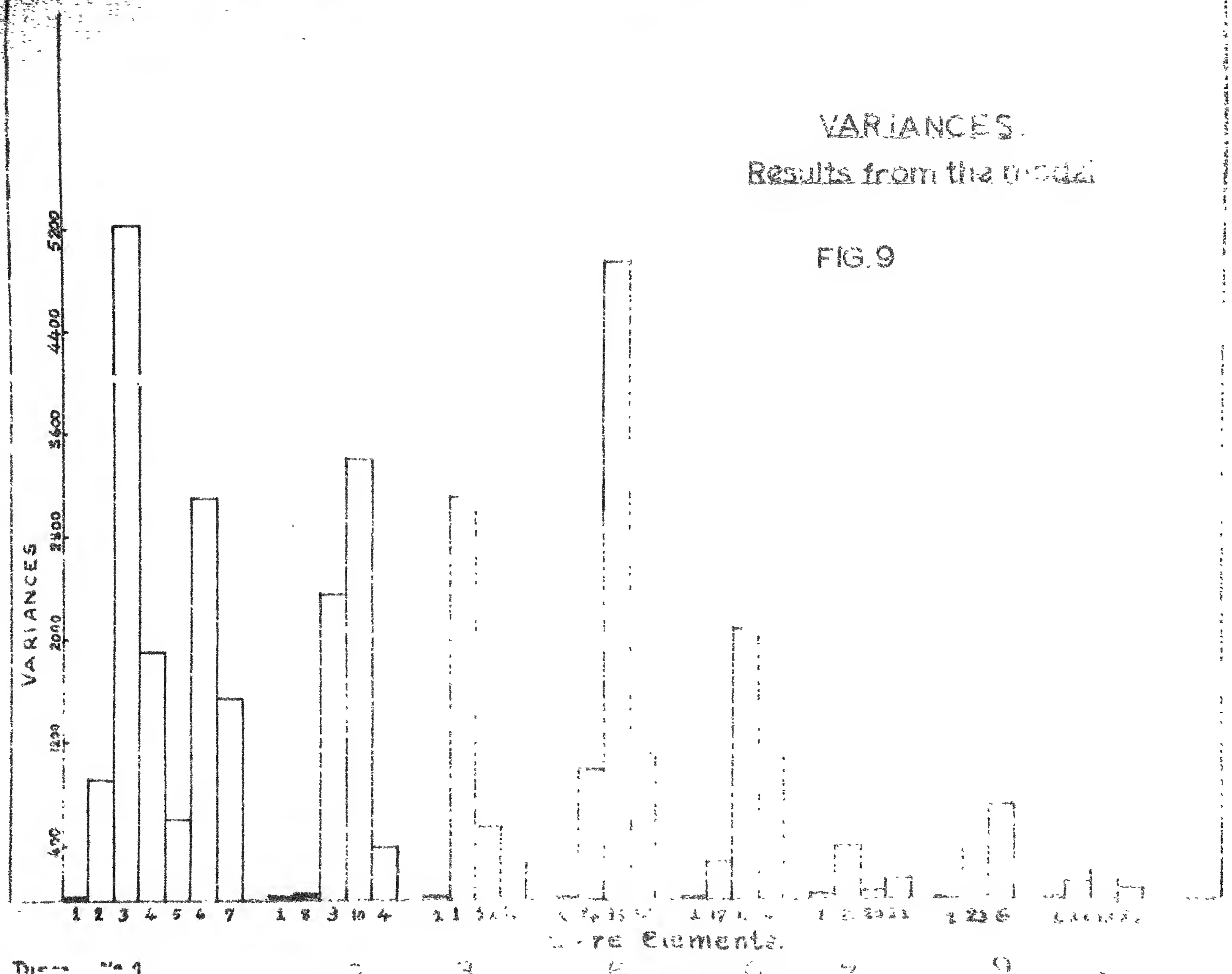
Results from the ...

FIG. 8.



VARIANCES.
Results from the model

FIG. 9



[redacted]

12. Richard D.Smallwood, et al, "Medical demand Model". Proc.of I.E.E.E.Vol.57, No.11, November 1969

13. ,"International classification of Diseases, Adopted", U.S. Department of Health Education and Welfare Volume 1, 1962

APPENDIX 1

Derivation of analytical results for average and variance of patient census and demand of services in terms of semi-Markovian parameters.

In the analysis of semi-Markovian processes, an important quantity is the interval transition probability $\phi_{jk}(n)$. It is the probability that a semi-Markovian process occupies k^{th} state after 'n' intervals of time after it enters j^{th} state. Superscript i, denoting disease is deleted hereafter. This interval transition probability is calculated from the basic parameters of semi-Markovian process, namely p_{jk} and $h_{jk}(n)$. Thus (11),

$$\phi_{ij}(n) = \delta_{ij}\ {}^{c}w_i(n) + \sum_{k=1}^{N} p_{ik} \sum_{m=0}^{n} h_{ik}(m)\ \phi_{kj}(n-m)$$

$$i = 1, 2, \ldots N\ ;\ j = 1, 2, \ldots N\ ;\ n = 0, 1, 2, \ldots$$

where $\delta_{ij} = 0$ if $i \neq j$

$= 1$ if $i = j$ and ${}^{c}w_i$ represents complementary cumulative mass function of residence times. It is defined as

$${}^{c}w_i(n) = \sum_{m=n+1}^{\infty} \sum_{k=1}^{N} p_{ik} \cdot h_{ik}(m).$$

In the present discussion, let $\phi_{\cdot j}(n)$ indicate the probability that a patient is in j^{th} state exactly n days after he entered the facility.

Another useful quantity is indicator variable $x_k^a(l,t)$ which is defined as

[redacted]

$x_k^a(1,t) = 1$ if the a^{th} patient who arrives at the facility on day 1, is in state k of the same disease on day t

$= 0$ otherwise

The expected value of this random variable is equal to the probability that its value is one which in our case is the interval transition probability $\phi_k(t-1)$. With this definition of the indicator variable, the various quantities discussed in Chapter 3 are written in terms of the indicator variable.

1. $\mu_k^i =$ Number of days a person stays in state k after he enters the facility.

There are several possible ways in which a patient can stay in k^{th} state for t days.

1. He can directly enter k^{th} state and remain there for t days in which case $\sum_{t=0}^{t} x_k^a(o,t) = t$

2. He can enter some other state and stay there for 1 day..and then enter k^{th} state to spend t days there, in which case $X_k^a(0,1) = 0$ $\sum_{t=0}^{t+1} x_k^a(0,t) = t$

3. He can enter k^{th} state after spending 2 days in some other states .....

and so on

adding up all these cases it makes upto t days. But by definition of $X_k^a(0,t)$, these make upto $\sum_{t=0}^{\infty} x_k^a(0,t)$

$$\therefore \mu^{i}_{k} = \sum_{t=0}^{\infty} x^{a}_{k}(0,t)$$

$$\bar{\mu}^{i}_{k} = E(\mu^{i}_{k}) = E\left[\sum_{t=0}^{\infty} x^{a}_{k}(0,t)\right]$$

$$= \sum_{t=0}^{\infty} 1.p\,(x^{a}_{k}(0,t) = 1)$$

$$= \sum_{t=0}^{\infty} \phi_{.}{}^{i}{}_{k}(t)$$

$$\bar{\mu}^{i}_{k} = \sum_{t=0}^{\infty} \phi^{i}_{.k}(t) \qquad - (1)$$

2.V^{i}_{jk} = Total number of days that a patient will occupy state j of disease i, with another patient occupying state k of the same disease, both having entered the facility on the same day. Similar to μ^{i}_{k}, we get,

$$V_{jk} = \sum_{t=0} x^{1}_{j}(0,t) \cdot x^{2}_{k}(0,t)$$

$$\bar{V}^{i}_{jk} = \sum_{t=0}^{\infty} \phi^{1}_{.j}(t) \cdot \phi^{2}_{.k}(t) \qquad - (2)$$

3.$n^{i}_{k}(t)$ = number of patients occupying the state k on day t $= \sum_{l=0}^{t} \sum_{a=1}^{\alpha_i(l)} x^{a}_{k}(l,t)$

$$\therefore \quad \bar{n}^{i}_{k}(t) = \sum_{t=0}^{t} \alpha_i(l) \cdot \phi^{i}_{.k}(t-l) \qquad - (3)$$

4.$D_m(t)$ = total number of service of type m demanded on day t

$$D_m(t) = \sum_{i,k} \sum_{a=1}^{n_k^i(t)} d_{km}^i(a)$$

$$\therefore \bar{D}_m(t) = \sum_{i,k} n_k^i(t)\, d_{km}^i \qquad - (4)$$

Similarly the variances of these quantities can be obtained by taking second moment with respect to the indicator variable.

APPENDIX 2

SAMPLE CALCULATION OF THE DEMAND.

For the purpose of illustrating the method of calculating the average demand and its variance, the disease dynamics of Hyper acidity is considered. The disease dynamics is shown diagramatically in Figure 6.

The input quantities of this disease are

1) Patient inflow = $\alpha_1 = 5$

2) Mean daily dosages of

a) Injection 1.0 - care element No. 1

b) Gelusil Tab. 35 tabs. care element No. 2

c) Enteriovioform 4.5 tabs.care element No. 3

3) Mean squares of the dosages

a) Injection 1.0

b) Gelusil Tab. 12.6 $(\text{Tabs.})^2$

c) Enteriovioform 22.5 $(\text{Tabs.})^2$

4) The transition probabilities and care elements in each state are,

a) State No. 1 0.5, 6, 23,25,29,30

b) State No. 2 0.5, 1, 6, 23

c) State No. 3 (0.5, 0.5), (0.5, 0.5), 6 and 23

d) State No. 4 (0.2, 0.5,0.5), (0.5, 0.5), 1 and 23

where 23, 25, 29, 30 are pathology tests.

5) The residence periods for the states are:

a) State No. 1 2 days

b) State No. 2 3 days

c) State No.3 7 days and

d) State No.4 7 days

Calculations:

$$\bar{\mu}_1 = 0.5 \times 2 = 1 \text{ day}$$

$$\bar{\mu}_2 = 0.5 \times 3 = 1.5 \text{ days}$$

$$\bar{\mu}_3 = 0.5 \times .0.5 \times 7 + 0.5 \times 0.5 \times 7 = 3.5 \text{ days}$$

$$\bar{\mu}_4 = 0.5 \times 0.5 \times 0.2 \times 7 + 0.5 \times 0.5 \times 7 = 2.10 \text{ days.}$$

$$\bar{n}_k = \bar{\alpha}_i \bar{\mu}_k^i$$

$$\bar{n}_1 = 5 \qquad D_M = \sum_k n_k d_{KM}$$

$$\bar{n}_2 = 7.5$$

$$\bar{n}_3 = 17.5 \qquad \bar{}_1 = 7.5 + 10.5 = 17.5$$

$$\bar{n}_4 = 10.5 \qquad \bar{D}_6 = 5 \times 3.5 + 7.5 \times 3.5 + 17.5 \times 3.5$$

$$= 105$$

$$\bar{D}_{23} = 5 \times 4.5 + 7.5 \times 4.5 + 17.5 \times 4.5 + 10.5 \times 4.$$

$$= 182.5$$

$$V(D_1) = \Sigma_k n_k a_{k1}^2 = 7.5 x + 10.5 = 17.5$$

$$V(D_2) = 12.5(5+7.5+17.5) = 375$$

$$V(D_3) = 22.5\ (5+7.5+17.5+10.5) = 910.0$$

REFERENCES

1. W.Grant Ireson and Eugene L.Grant, "Hand Book of Industrial Engineering and Management" - Engle Wood Cliffs N.J., Prentice Hall Publication 1971.

2. Hallford. E. Smalley and John. R.Freeman, "Hospital Industrial Engineering". New York, Reinhold 1966

3. Marris Asimow, "Introduction to Design". Engle Wood Cliffs N.J. Prentice Hall 1962

4. Har. Bhajan Singh, "Air Pollution Study of Kanpur City"., M.Tech., Thesis, I.I.T. Kanpur 1969

5. ,"International Standards, for Public Health", W.H.O. Publication.

6. Sachan, P.C., "Characterisation of Waste water of I.I.T. Kanpur", M.Tech. Thesis - I.I.T. Kanpur 1968

7. A.D.Hall, "A Methodology of systems Engineering". Van.D.Nostrand, 1964

8. Jeet Raj Sehgal, "Field investigation on a waste water Sabilization pond", M.Tech. Tehsis, I.I.T.Kanpur-1969

9. Srikrishna Srivastava; "Treatment of water by foam Floatation". M.Tech. Thesis I.I.T. Kanpur 1972

10. Nagaraj Murthy, " Systems Approach to Health Care Problems" M.Tech. Tehsis - I.I.T. Kanpur - 1972

11. R.A.Howard, "Dynamic Probabilistic systems". John Wiley & Sons Inc. New York 1971.